

AEROBUS - THE AIRCRAFT OF THE FUTURE
(BASIC PROBLEMS OF DESIGNING AIR BUSES)

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AEROBUS - THE AIRCRAFT OF THE FUTURE
(BASIC PROBLEMS OF DESIGNING AIR BUSES)*

[Article by V. Sheynin, Candidate of Technical Sciences, Lenin Prize Laureate; Moscow, Grazhdanskaya Aviatsiya, Russian, No 1, 1972, pp 24-27]

In the Ninth Five-Year Plan, highly economical new-type aircraft will be put into operation. The construction of an air bus for 300-400 passengers is planned. Some problems of building the air bus and the characteristic features of transporting baggage in it are discussed in this article. The author has touched on the problems of interest both to designers and operators.

The concept of the air bus is not new. Sixteen years ago it was encountered in papers by the young Russian engineer B. N. Yur'yev (later to become a famous Soviet scientist and aerodynamicsspecialist). It was defined as an "air-plane capable of lifting a large number of passengers."

The development of passenger aircraft of all classes is accompanied by continuous growth of their seating capacity. However, for future development a simple increase in the number of seats has become insufficient. New solutions are required which will permit correspondence of the growing volume of transport operations and increase in passenger traffic density to the organization of the transportation system as a whole. This has become the primary reason for generation of the idea of organizing transportation operations of the air bus type, that is, the idea of the air bus. Another reason for the generation of this idea is the effort to eliminate the lack of correspondence of the flight time to the time spent by passengers before and after flight (acquiring tickets, traveling to the airport, checking and picking up baggage, and so on). The fact is that systematic increase in speed has noticeably reduced the flight time, but the total time spent by the air passenger "from house to house" has not been significantly reduced. Finally, the third reason, but not the last with respect to significance, is the effort to improve the economy of the transportation operations. There are different means of

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solving this problem. One of them is to reduce the various types of aircraft represented by the air fleet. The conditions of development of jet aviation have led to the formation of four classes of main route aircraft (short-range, medium-range, long-range and intercontinental). In addition, there are aircraft in operation from a minimum of two generations which further complicate the matter. Having different types of aircraft increases the cost of the fleet and the operating and maintenance costs. Therefore, when developing air buses a trend toward building wide-range aircraft appeared.

The ideas which have now developed are leading to a broader definition of the air bus concept. This is a short-medium-range aircraft with large seating capacity, high economy and improved comfort insuring (together with ground facilities) maximum reduction of preflight and postflight time and corresponding to the requirements of the new organization of traffic on the airlines. From the purely technical side, the air bus is a multiton broad-fuselage aircraft with high commercial effectiveness and relatively short range.

The primary new thing that air buses provide consists in the quantitative jump which leads to new qualitative content.

Not one type of aircraft built in the past has represented such prolonged design development and such prolonged discussion, and the discussed problems were never of such a disputable nature as in the case of the air bus. The problems of seating capacity and flight range, the number and composition of the engines, the size and shape of the fuselage were disputed.

The problem of transporting passenger baggage determining the very concept of the air bus was the most argued. The idea of take-on baggage, that is, carrying personal baggage as on the railroad, came up when studying this problem. Several versions of solving the problem on the basis of the three main conditions -- comfort, weight, economy -- were investigated. A study was made of all possible "pros" and "cons." The problem turned out to be unexpectedly complicated and contradictory.

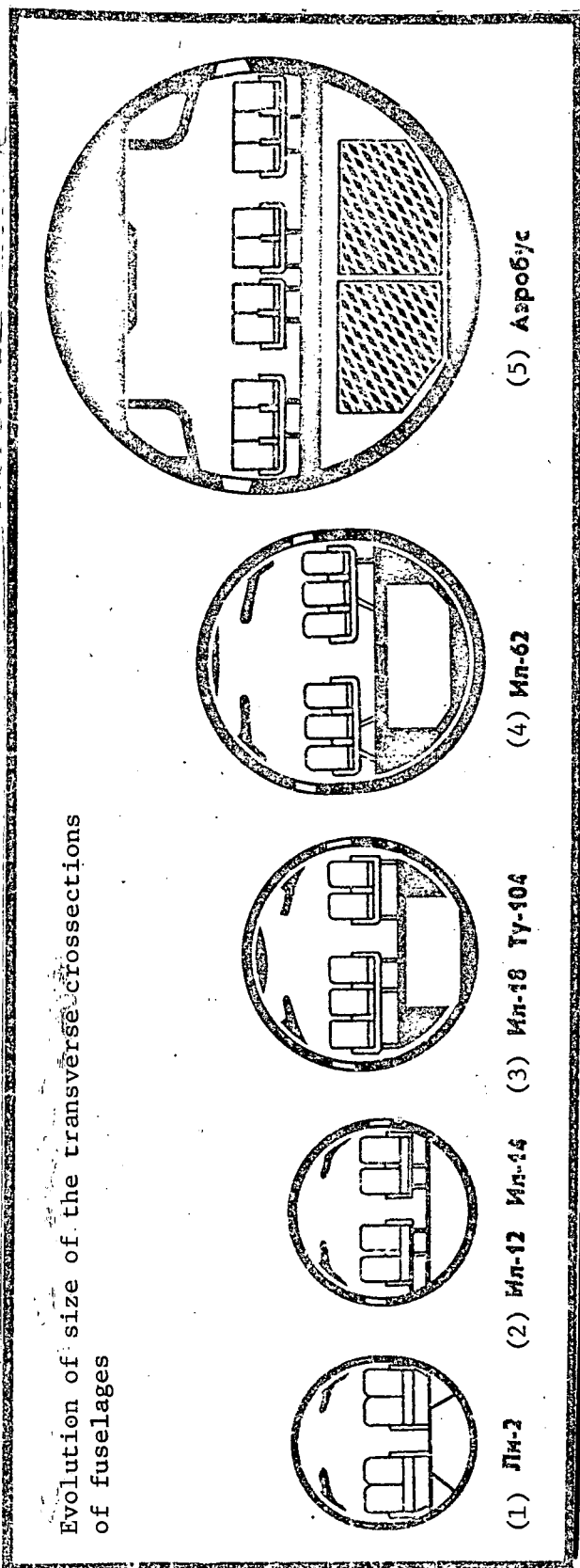
Recently, passenger aircraft with gas turbine engines have provisionally been divided into generations each of which reflects a certain stage of development of aviation engineering. It turns out that the first generation includes turboprop aircraft: the Il-18, An-10, Tu-114, An-24 and the turbojet Tu-104. The second generation includes aircraft having bypass (turbofan) engines aft of the fuselage: the Il-62, Tu-134, Yak-40 and Tu-154. The primary distinguishing feature of aircraft of the third generation is a broad fuselage and large engines with a high degree of bypass. Figure 1 shows how the size of the fuselage has changed in the last 30 years. The break has only just taken place.

It is understood that not all the third generation aircraft will be wide-fuselage. Air ships of lesser size are also being developed for lines on which significant increase in passenger traffic is not forecasted.

The primary design problem has always been the problem of size and weight of the aircraft. During the time of development of wide-fuselage aircraft, this problem has become especially acute. It must be noted that the

Figure 1.

Evolution of size of the transverse crossections of fuselages



Key: 1. Ли-2 2. Ил-12, Ил-14 3. Ил-18, Ту-104 4. Ил-62 5. Air bus

concept of "aircraft size" includes not only the linear extent of the individual elements and the area and volume depending on them but, to an equal degree, the characteristics such as mass of the airship. During the development process, the latter has increased more rapidly than the geometric size. Thus, during the 1900-1971 period, the wing span increased by six times, the area by twelve times, and the takeoff weight of the aircraft, by a thousand (!) times. The characteristics such as takeoff weight (or tonnage) and weight of the empty aircraft obviously are the most acceptable for determining the size.

During the aircraft development process, the increase in the tonnage went smoothly with one and the same type of engine (Figure 2) and discontinuously when a new type of engine appeared. The smooth increase is connected with improvement of the aerodynamics of the aircraft and the engine characteristics. A consequence of this is an increase in the weight return and flight range, that is, the efficiency and economy. The greatest jump was observed when building the air bus which with respect to tonnage exceeds the intercontinental aircraft although it is used on short and medium trips.

Thus, in achieving high transport efficiency and lowering the cost of transport operations it is necessary to build aircraft of maximum size, of course, within the limits of the technical possibilities at each stage of development and practical necessity for air transportation and also with given efficiency--- minimum size. This is one of the basic rules of designing civil aircraft. However, each level of development corresponds to a defined limiting size connected with achieving the greatest efficiency (optimal size). Aircraft with greater than limiting dimensions either have been inexpedient or could not be built. It is true that "premature" aircraft with dimensions exceeding "largest" have appeared. They can provisionally be called one-parameter aircraft inasmuch as the sacrifice to size has brought other advantages. Such aircraft have been distinguished either by great load per unit power or small wing load or low speed.

During the period of piston aircraft, the increase in size was blocked by the possibilities of the power plants. The introduction of turbofan engines with a high degree of bypass removed these restrictions (this explains the sharp change in the slope of the lines in Figure 2 corresponding to wide-fuselage aircraft). Therefore, a study of the required size of such aircraft has been based on forecasts of the growth of transport operations for the next decade. The basic design problem has become maintenance and further reduction of the relative structural weight, that is, breaking the "weight barrier."

The configuration of the air bus fuselage has also been the subject of long studies. A circular transverse cross section and a single-deck system (the subfloor cargo compartments are not considered a deck) were not adopted immediately.

When designing the third generation aircraft it was necessary to depart from standard fuselages because they do not correspond to the required magnitude of the total commercial load and the number of passengers which has at this time increased sharply. In addition, the increase in freight transport operations

has required the organization of transportation of them in containers the sizes of which are beyond the possibilities of aircraft in operation at the present time. For these two reasons, the idea of a large fuselage of optimal configuration arose.

The composition of the compartments and creation of passenger comfort are directly related to the size and configuration of the fuselage. The problems of comfort pertain to the design problems which are solved on the basis of a compromise between the trend toward raising the level of requirement and the trend toward improving economy. In the given case, this must be understood as follows. A high level of comfort which attracts passengers will promote an increase in load and, consequently, an increase in economy. However, in addition, the weight of the equipped aircraft will increase (as a result of reducing the degree of utilization of the fuselage volume), which has the opposite effect.

The comfortable chairs, the low noise level, good air conditioning and the compartment interiors used for second generation aircraft -- all of these have acquired the international standard category. The wide fuselage air buses are another matter. The problem of their interiors must be solved in a different way. The search for an efficient number of seats has shown that the composition of the cabins with ten seats in a row is permissible only for very short flights. Their optimal number does not exceed eight-nine with two longitudinal aisles the width of each of which is increased by comparison with the single-aisle fuselages. The transverse aisles and entry doors the dimensions of which accommodate two passengers simultaneously have become larger.

This composition of the compartments and also the freer arrangement of the seats of improved design and somewhat larger dimensions, the expanse of high compartments, large baggage racks, closed flaps and high level of over-all comfort -- all of these distinguish the inside shape of the air buses. In a liner compartment, provision is made for movies, tape recorders and television. Spacious buffets are located under the floor of the compartment. The distribution carts are raised by elevators.

Selfpropelled cars for 150 people raised on their own lifts are being built to transport passengers from the airport to the aircraft. These cars are equipped with air conditioning and heating.

It is of interest to mention the following: when building second generation aircraft and versions of them, an effort was made to improve the composition density of the cabins and the degree of utilization of the fuselage volume. Thus, by lowering the comfort, the profitability of the aircraft was raised. When developing third generation aircraft the trend toward improving comfort became obvious. This can be seen in the efforts to attract passengers, that is, to improve the ticket demand required in connection with the sharp increase in number of proposed seats.

Another no less complex problem of building air buses is selection of the number and composition of the engines. The second generation aircraft with

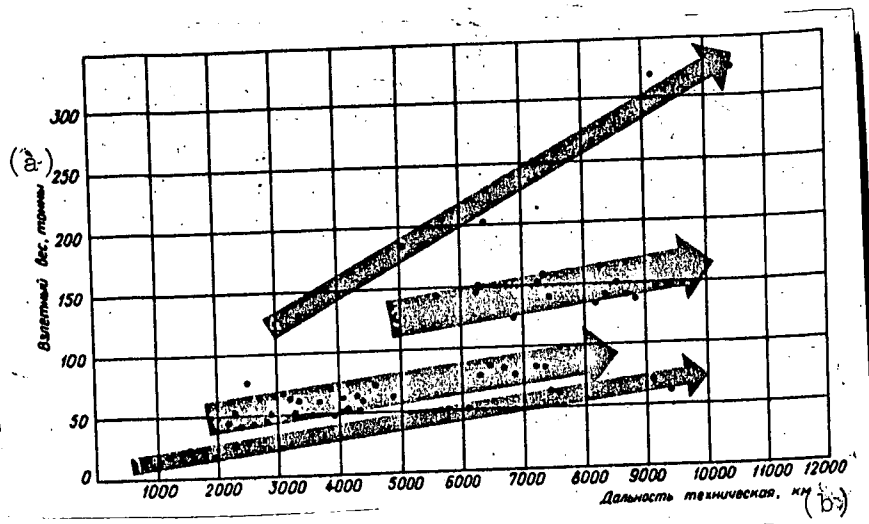


Figure 2. Years put into operation:
 1 -- 1930-1950; 2, 3 -- 1950-1970; 4 -- 1970-1975. Engine types: 1 -- piston engines;
 2 -- turboprop engines, turbojet engines, turbofan engines; 3 -- turbofan engines;
 4 -- turbofan engines (m = 5-6) wide-fuselage aircraft
 Key: a. takeoff weight, tons
 b. technical range, km

tonnage corresponding to the air buses have four engines. The advantages of the power plants with a high degree of bypass (low specific weight and fuel consumption) are exhibited in full measure with a thrust higher than 16,000-18,000 kg. Therefore, when designing the first air buses, the problem of using two and three engine systems for aircraft weighing 120-150 and 180-200 tons, respectively, arose.

The four-engine system was born and proved itself during the period of piston aviation when insurmountable obstacles arose for further increase in power of the engines. However, the main thing was that the power plant insured flight safety with minimum expenditures. The three-engine system now used arose from the possibility of arranging the engines aft. A significant role was also played by the fact that the weight and economic characteristics of aircraft with three and four engines are similar under aircraft design conditions with an equal degree of safety and equal efficiency. The three-engine system with two engines under the wings and one aft first appeared in the Tu-14 aircraft in 1947. Now it is used on American air buses. The application of the two-engine system when designing short-range turbojet aircraft (the Caravelle, the Tu-134, Dc-9, the Boeing-737, the Bak-111, and the Dasso Merkyur) with almost

doubled tonnage (by comparison with the two-engine piston aircraft) aroused no doubts. The fleet of such aircraft, it is true, initially (for two or three years) grew slowly and then very rapidly. This is connected with an increase in the trust in the two-engine system, and primarily with the development of bypass engines economical two-engine aircraft could be built with the required degree of safety.

When the concept of short-range third generation aircraft with high seating capacity was formed, the two-engine system was the subject of prolonged discussion. The Europeans have been for two engines for aircraft weighing 120-140 tons with a 2,100 km flight range, and the Americans, three engines (180-200 tons and 4,300 km). An air bus weighing 180-200 tons can be highly economical, and with four engines with medium bypass having low specific rate and fuel consumption, they have high reserve and reliability indexes. The choice of engines for European and American air buses has undoubtedly been influenced by preliminary development of them for competition with the Lockheed C-5A transport aircraft. As for the relation of the number of engines to the flight range, there are defined range limits after which three engines become better than two, and four better than three (under other equal conditions).

When designing an air bus together with improving its flight characteristics (flight speed) and increasing the geometric parameters (fuselage length and diameter), qualitatively new phenomena appeared leading, in particular, to re-evaluation of the advantages and disadvantages of the aft engines. This system as applied to wide-fuselage aircraft has eliminated many of its advantages which it had previously on second generation airlines. The nature of its deficiencies (in qualitative and quantitative respects) also changed simultaneously. Therefore, the choice of arrangement of the engines became a problem of taste of the designers, more precisely, their skill (experience) in achieving maximum advantages from the version to which preference was given.

Recently, we frequently hear about the efficiency not only of machines but systems of machines (in the given case, aircraft and transport systems). Economically, the efficient aircraft is the one which is capable of completing a scheduled flight at minimum cost per aircraft-hour. The latter includes the direct expenditures on fuel, wages for the crew, depreciation of the material part and indirect expenditures -- the airport servicing costs. Efficiency is obtained only as a result of efficient solution of all the design, construction and operation problems. Some part of them, of course, is always the determining factor. When developing air buses, the primary problems were the problems of fuselage size, weight and drag of the aircraft.

As for the flight speed determining the hourly output and, consequently, the economy, it increases in the case of air buses. With each new generation of jet aircraft, the flight speed increases approximately by an amount corresponding to $M = 0.05$. A jump in speed will take place, as is known, on introduction of supersonic passenger aircraft, for example, the Tu-144. However, subsonic aircraft will remain for many years the primary workers in the sky. When supersonic aircraft take their place, they will become rivals of the subsonic aircraft. These types of aircraft will supplement each other.

The success of modern passenger aircraft depends to an enormous degree not only on efficiency but also on maximum reliability of the systems, flight safety and traffic regularity. These problems are especially acute for the air bus builders. This is entirely understandable, for there will be hundreds of passengers on board these giants.